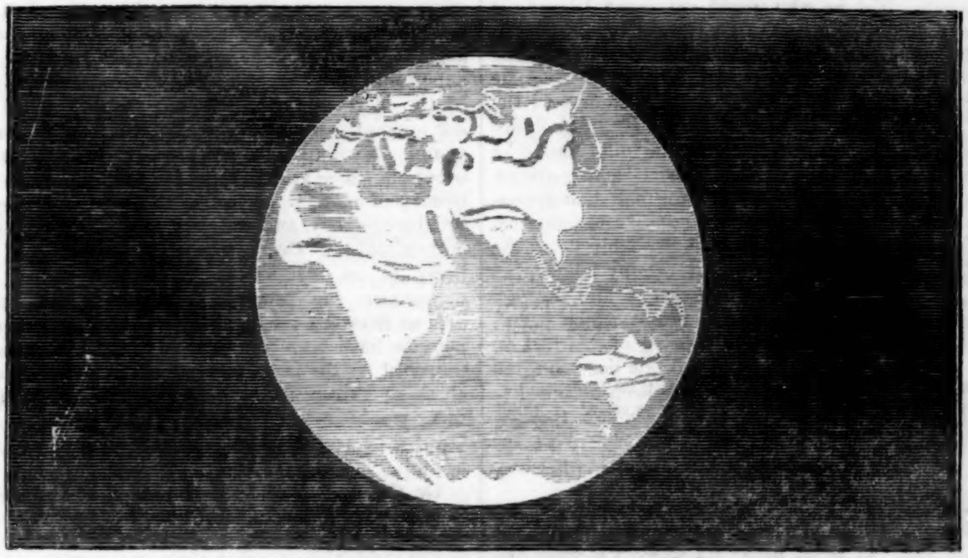
THE
Saturday Magazine.

THE SOUL BE WITHOUT KNOWLEDGE IT IS NOT GOOD

Nº 401. SUPPLEMENT, SEPTEMBER, 1838. { PRICE ONE PENNY.

POPULAR ASTRONOMY. PART III.



THE PROBABLE APPEARANCE OF THE EARTH TO THE MOON.

THE EARTH.

. . . . . . What if the Sun
Be centre to the world, and other stars
By his attractive virtue and their own
Incited, dance about him various rounds?
Their wandering course now high, now low, then hid,
Progressive, retrograde, or standing still,
In six thou seest, and what if seventh to these
The planet Earth, so steadfast though she seem,
Insensibly three different motions* move?
MILTON'S *Par. Lost*, b. viii.

WE have now arrived at the third planet in the order of distance,—the Earth, on which we dwell: that habitation which, though it may appear so vast—so mighty—to our gaze, is but a speck in the great scheme of the universe. Could we but travel into space, and view the solar system as a connected whole, how small would our Earth appear, and how unworthy of the boastful importance which we are apt to attach to it! If there be inhabitants on any of the exterior planets, they see the Earth merely as a small star, shining by the light which she receives from the Sun, and which she reflects from her own surface.

That the Earth is round the proofs are many and easy: for, in addition to the gradual appearance, from the top downwards, of a ship coming into port, and the fact of the world having been sailed round, which amounts to practical conviction,—yet, as this sailing has always been in the direction of East and West, the Earth might be cylindrical, and this Eastern and Western circumnavigation still have taken place; but, in sailing southward, we observe that the fixed stars in the Northern heaven sink down towards the horizon, and the Southern stars keep on rising in the sky; the reverse taking place as we return northward. This circumstance is beautifully alluded to in the *Lusiad* of Camoëns, a Portuguese poem, relating to the discovery of India.

O'er the wild waves as southward thus we stray,
Our port unknown, unknown the watery way;
Each night we see, impressed with solemn awe,
Our guiding stars and native skies withdraw:
In the wide void we lose their cheering beams:
Lower and lower still the Pole-star gleams,
Till past the limit, where the car of day
Rolled o'er our heads, and poured the downward ray,
We now disprove the faith of ancient lore;
Boötes' shining car appears no more:
For here we saw Calisto's star retire
Beneath the waves, unawed by Juno's ire.

The latter part of this quotation implies, that when the navigators had got some way below the tropic of Capricorn, they lost sight of the constellations Boötes and the Great Bear.

The Earth, however, like all the other planets, is not quite of a globular shape; and, before we proceed further, it may be desirable to explain why it is that none of the planets are precisely globular, but are somewhat flattened at two opposite sides, into a shape which is called an oblate spheroid, but which will be sufficiently comprehended, if we compare it to an orange.

All the planets, besides revolving round the Sun, have, as we said, a revolution on their own axes; that is, they spin round like a top. What may have been the original cause of this motion has never been discovered. We can only conclude that it was given to those bodies by the great Creator, for his own wise purposes, and according to his own fixed and inscrutable decree. Hidden as the cause of this motion is from us, we can, however, trace its effects in many important circumstances; one of which is, the oblateness, or flattening of the revolving bodies. There is a kind of force called *centrifugal*, occasioned whenever a spinning round is performed: this force tends to throw the body, or anything which rests upon that body, away from the centre as far as possible, and may be illustrated in a variety of ways. A pail of water may be suspended by a rope, and turned rapidly round in a vertical circle without wasting a drop of the water; although in every revolution, the pail, and the water which it contains, strive to recede from the hand, which is the centre of motion, as far as possible, during the revolution, by virtue of the *centrifugal*, or *centre-flying* force, which is imparted to them in proportion to the rapidity of motion. When the pail is upside down, the natural tendency of the water is to be poured out towards the ground; but this tendency is counteracted by the centrifugal force, which tends to drive the

* The annual, diurnal, and libratory motions, explained in this paper.

water away from the central force which retains it. It is on a similar principle that a slinger propels a stone to a great distance: the hand is the centre of motion; and he turns the stone rapidly round in order to gain for it a centrifugal force, which shall carry it to a great distance, as soon as it is released. If we drive a wire through any round body, and make the surface of this body equally wet all over, and then spin it round by means of the wire, the moisture will be collected in greater quantity at those parts of the surfaces most removed from the wire: while, at the parts near the wire, the quantity will be diminished: the centrifugal force urges the fluid away from the central part to the part furthest removed from the wire; which part describes the largest circle in going round.

Now, the same line of argument will apply to a revolving planet: the surface of the Earth moves round its axis (an imaginary line, the extremities of which are called its *poles*,) with a velocity of 1042½ miles per hour, at the equator, a line supposed to be drawn all round the globe, at an equal distance from the two poles and at right angles with the Earth's axis. It is clear, therefore, that the velocity of the rotation of any part of the Earth's surface must diminish as we recede from the equator and approach the poles. But, as the equatorial parts especially, acquire such a vast centrifugal power, the effect of it is, that the Earth bulges out at those parts most removed from the axis of rotation. The extent, to which this bulging has been carried in the case of the Earth, during the lapse of nearly sixty centuries, will be seen from the following dimensions:—the smaller diameter of the Earth, measured along the polar axis, is 7899 English miles; and the greater diameter, which is the diameter of the equator, is 7926 miles, which, therefore, exceeds the other by about twenty-seven miles: if we take the average of these two diameters, we may say that the Earth's diameter is about 7912 miles: consequently, the circumference of the Earth amounts to 24,899 miles.

Our planet, when in *perihelion*, that is, at *its nearest point to the Sun*, is about ninety-three millions of miles distant from the Sun, and about ninety six millions of miles distant therefrom, when in *aphelion*, that is, *the point furthest removed from the Sun*. These two terms will be understood by referring to the ellipse, or oval, which was represented in our first paper: the Sun is situated, not in the centre, but in one focus of the ellipse; and when the Earth is nearest to the Sun's focus, she is said to be in *perihelion;* when farthest therefrom, in *aphelion*. Hence, its average distance from the centre of its annual motion, is about ninety-five millions of miles.

The path, which the Earth describes round the Sun, is, therefore, an orbit of about six hundred millions of miles; and this enormous distance she traverses at the rate of 68,000 miles an hour, or about nineteen miles in a second, in 365 days, 5 hours, 48 minutes, and 49 seconds, being the period to which we give the name of *year*. If the Earth did not revolve on her axis, we, who inhabit its surface, should see the Sun apparently making a revolution round the Earth in the course of a year: a revolution which, however, would be altogether imaginary, owing to the fallacy of the evidence of our senses. The Earth moves in her orbit; but we cannot see that it is moving, because we are on its surface, and are moving in a like direction, and with a like velocity. The motion of the Earth is of a smooth, equable, and unimpeded kind; which sort of motion, if we experience anything like it by land or water, our senses may be lulled into a forgetfulness of our being carried along, while the stationary objects on either side,—the hedges, trees, banks, &c.,—seem endued with motion, and glide rapidly past us. If this be the case with respect to the annual motion of the Earth round the Sun, how much more forcible is the application of this analogy to the diurnal motion of the Earth on her axis! The Sun, the planets with their moons, the comets occasionally, and innumerable fixed stars, are placed in an apparent hollow sphere around us; and as we come opposite to different parts of the heavens in succession by our diurnal rotation, it appears to us as if the whole of this concave sphere kept on revolving round our Earth.

The term of a *year*, just spoken of, is the time taken up by the Sun in passing, apparently, from a particular point of the ecliptic to the same point again: say, the first point of Aries, being one of the two points, where the equator and ecliptic cut each other. This is called the *solar*, or *tropical* year, the time it takes the Sun to visit the tropics and return to the equator; whereas, the time taken up by the Sun, in passing from a certain fixed star to the same star again, consists of 365 days, 6 hours, 9 minutes, and 12 seconds, and is called the *sidereal* year; the year as determined by observation of a particular star. This latter is twenty minutes, twenty-three seconds, longer than the former; and is owing to a slow, but constant, alteration of the position of the equinoctial points.

The actual time in which the diurnal revolution of the Earth is completed, is 23 hours, 56 minutes, and 4 seconds; but, owing to the motion of the Earth in her orbit at the same time, it is twenty-four hours, upon an average, throughout the year, before the Sun can pass from the meridian of a place to the same meridian again. This meridian implies a line drawn from North to South, going through any particular place, to which line the Sun becomes vertical every day at noon.

The axis, on which the Earth is supposed to revolve, is inclined to the plane of the Earth's orbit, or ecliptic, at an angle of about 66½ degrees. Now, as the plane of the equator is perpendicular to the axis of the earth, it follows that the plane of the equator is inclined to the plane of the ecliptic at an angle of about 23½ degrees. Very remarkable and important effects result from the rotation of the Earth on her axis, and from the obliquity of the equator with the ecliptic, which effects will occupy our attention more particularly in the next paper.

We have already seen that the Earth is not now a perfectly geometrical globe; and it would strike us that, if there were no other cause to interfere with its due form, the existence of mountains and valleys on its surface is sufficient to disturb the tiny conception we have at first regarding

> This pendant world, in bigness as a star
> Of smallest magnitude close by the moon.
> MILTON'S *Par. Lost*, b. ii.

But our conceptions of the extent of the earth's surface, which are contracted when we compare the Earth with the universe, become enlarged by referring it to ourselves. Hence, by instituting an arithmetical comparison between the Earth and a globe of eighteen inches diameter, if we wished to form at its proper place on the latter, and in its proper proportion, the very highest mountain in the world, which is the Chumularee, belonging to the Himalayah range, in Asia, and 29,000 feet in height, the elevation on the artificial globe would be about the one-fiftieth of an inch.

It is probable that the Earth serves, only in a more efficient manner, the same purpose to the Moon that the Moon serves to the Earth; undergoing all the changes which we see in the Moon, and appearing nearly thirteen times larger, and consequently much more brilliant. Its appearance to the Moon is represented at the head of this paper. This representation is, of course, fanciful; and to estimate it fairly we must indulge ourselves in the supposition that the lunar inhabitants, if there be any, are, for the most part, in similar circumstances with ourselves.

We have before stated that the diameter of the Sun is 111 times as great as that of the Earth. Now this proportion makes the solar globe to be, as a whole, 1,384,472 times as large as the globe of the Earth; though the density of the latter is about four times as great as that of the former. The average density of the Earth is 4½ times that of water: so that it would seem that the Sun is composed of matter somewhat more dense, or consistent, than water.

THE MOON.

> ....Meanwhile the Moon
> Full orbed, and breaking through the scattered clouds,
> Shows her broad visage in the crimsoned East.
> Turned to the Sun direct, her spotted disk,
> Where mountains rise, umbrageous dales descend,
> And caverns deep, as optic tube descries,
> A smaller Earth, gives us his blaze again,
> Void of its flame, and sheds a softer day.
> Now through the passing cloud she seems to stoop,—
> Now up the pure cerulean rides sublime.—THOMSON.

When the poet wrote these beautiful lines, we can imagine, from the context, that he was under the influence of those feelings, which are produced in men by the aspect of the quiet, moon-lit scene of nature; when the tumults, excited by day, and the passions roused by intercourse with fellow-mortals, are becalmed by the clear, cold, silence, which pervades the open country; such as makes melancholy have something of a pleasing turn, when we love to walk forth—

To behold the wand'ring Moon,
Riding near her highest noon,
Like one that had been led astray
Through the heaven's wide pathless way,
And oft, as if her head she bowed,
Stooping through a fleecy cloud.—MILTON'S *Il Penseroso.*

We will consider chiefly the circumstances which relate to the Moon as a celestial body, independant of the Earth.

The Moon is about 2060 miles in diameter; that is, her diameter is rather more than a quarter of that of the Earth, which is about fifty times the size of the Moon. Her mean distance from the Earth, as calculated from her horizontal parallax, is almost 240,000 miles; and she moves in her course round the Earth at the rate of about 2290 miles per hour.

The Moon shines by reflecting the Sun's light, as first supposed by Thales, the Grecian astronomer. Plato supposed that it was composed of fire; and Aristotle, that it shone by its own native light. The Moon's light has been found, as far as our means of observation extend, to be quite devoid of heat. This fact has been proved by concentrating 306 times the rays of the full Moon, when on the meridian, by a powerful burning-glass of three feet in diameter; the focus of which rays has not affected the most delicate thermometer. It has been shown by experiment, that the light of the Sun is 300,000 times greater than that of the Moon. Now we will suppose that the heating power of the Sun, compared with that of the Moon, is in the same proportion. The direct rays of the Sun are capable of elevating the thermometer 237°. The Moon's beams would therefore raise the thermometer, according to this calculation, only $\frac{1}{1250}$th of a degree; and, if these moon-beams were concentrated 306 times, the elevation of the thermometer might be $\frac{1}{4}$ of a degree. But, even this calculation is considered to be too favourable to the heating power of the moon-beams, and cannot be borne out by experience.

The Moon, then, not possessing any heating rays, that are cognizable by man, does not seem likely to possess or exert any influence over the herbs, flowers, and other productions of the earth, as was imagined by the old botanists. We read in the 33rd chapter of Deuteronomy, verse 14, where Moses, the Jewish lawgiver, speaks of the blessings of Joseph, that he refers to "the precious fruits brought forth by the sun, and the precious things put forth by the moon." We ought to observe that, in the original Hebrew, the word *moon* is used in the plural number; and in the next place, commentators have offered two senses of the latter phrase:—first, it may imply the productions of the ground made to spring up by the dews, which descend at night, when the Moon is visible; or, secondly, we may understand the productions of the earth, which appear respectively in their different *months*, or *moons;* the former of these two words being only a derivation of the latter.

The inclination of the Moon's axis to the plane of the ecliptic is only about $1\frac{1}{2}$°; so that her seasons are permanent and without variety. The density of the Moon is considered to be somewhat greater than of the Earth.

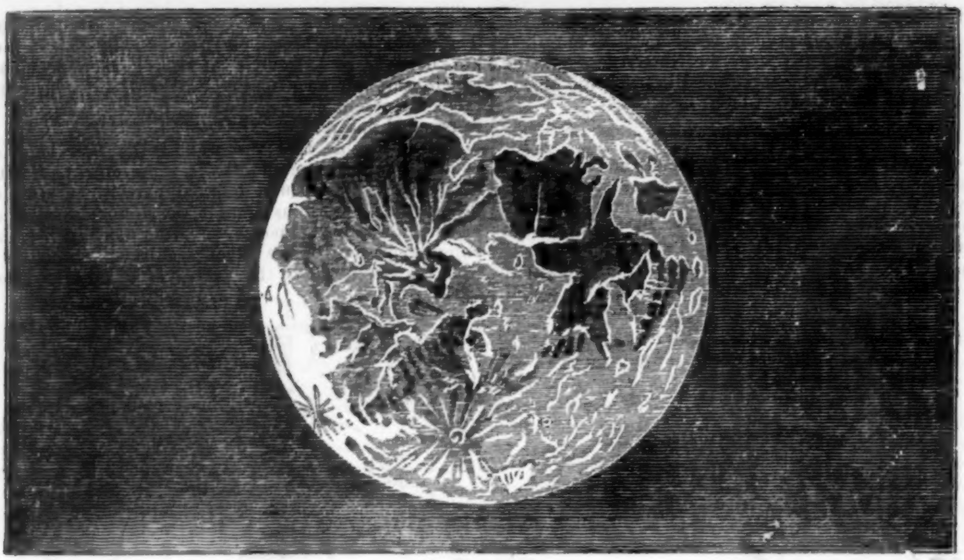
The Sun and the Moon have always attracted the attention of mankind more than the other celestial bodies, owing to their greater apparent size, and direct influence upon our globe. The Moon, revolving round the Earth, is called the Earth's *satellite*, or *attendant.* When the full Moon is viewed through a powerful telescope, her illuminated surface appears interspersed with dark spots and ridges, of every variety of shape, as represented in the subsequent figure; which kind of representation of the Moon was first sketched out by Hevelius, in the year 1645.

There are valleys, or hollows, which are supposed to be three miles deep, and are surrounded by nearly circular margins, a phenomenon to which the Earth cannot afford a parallel. The spots have been so carefully noticed, that a catalogue of 89 of them has been prepared, in which a description of the form and appearance of each spot, and of its exact position on the Moon's surface, is given. The spots have had fanciful names applied to them,—sometimes they have been named after distinguished individuals, while at other times they have been named after certain places on the Earth's surface, such as Byzantium, Caucasus, Sogdiana, &c. The heights of the mountains, which have been observed on the Moon's surface, are very variously stated by different authors, according to the modes in which the observations were made:—one of these modes was to measure the lengths of the shadows, cast by the mountains, in consequence of the light of the Sun coming in a particular direction, the shadows being then compared with the whole diameter of the Moon. The bright spots are held to be the tops of lofty mountains illumined by sunshine; two or three of which Dr. Herschel observed to be of a volcanic nature, and to emit flames and smoke. The best authorities make the highest of these mountains less than two miles in height. Generally speaking, the dark parts are thought to be water, and the bright parts land; the former absorbing, and the latter reflecting the solar rays: while, at the same time, many astronomers think that there is not much water in the Moon, owing to the usually serene appearance of her disk, which seems free from clouds and undisturbed by fogs and vapours. If there be little or no water in the Moon, this circumstance may account for the vast hollows just spoken of; which sort of appearance the Earth might present if the oceans and lakes were suddenly drained off. But, in respect of the details of the surface of the lunar globe, there exists much variety of opinion among astronomers.

The Moon is presumed to have no atmosphere, or one which is of a very thin character, because there have not yet been observed any effects of refraction, whereby the forms of planets, when being *occulted*, that is, passed over and *hidden* by the Moon, would appear distorted just before the act of occultation. This effect would result from the star or planet being seen through the Moon's atmosphere. But there does not seem an universal opinion among astronomers on this point; as several have recently given accounts, which, if correct, would lead us to conclude that there was a lunar atmosphere; while others say decidedly that there is not: it seems, however, to be agreed that the atmosphere must be of a very rare character.

The Moon revolves in her orbit round the Earth at the same time that the Earth itself is revolving about the Sun: the consequence of which is, that the Moon traces a sort of spiral line round the Sun; because, by the time the Moon has made one revolution round the Earth, the Earth has performed nearly one-twelfth part of her annual circuit round the Sun. The Moon goes round the Earth about $12\frac{1}{4}$ times in the course of a year; and the actual time taken up by the moon in performing this circuit is about $27\frac{1}{3}$ days; but the time from new moon to new moon again is about $29\frac{1}{2}$ days. To each of these periods of time has been given the name of *month;* the former being called *periodical,* comprising the *period* of the Moon's course round the Earth; the latter *synodical,* or the month, as agreed upon by men in the infancy of society, and determined by *the coming together* of the Sun and Moon. The reason why the latter is longer than the former is, that, although the Moon might actually pass round the Earth in $27\frac{1}{3}$ days, if the Earth were still; yet, a longer time is consumed from one phase of the Moon to the same phase again, owing to the motion of the Earth in its orbit, in the same direction as the Moon's motion, from west to east; so that the extra $2\frac{1}{4}$ days are spent by the Moon in fetching up the overplus of the progress made in the mean time by the Earth.

The Moon revolves on an axis, and it is remarkable that the time of this revolution is just equal to the time which she takes to revolve round the earth; a consequence of which is, that the Earth always has the same side of the Moon presented to it. The inhabitants, if any, on this side the Moon have the Earth always before them, while those on the remote side of the Moon can never be blessed with the view of it. The disk, which the Earth must exhibit to the inhabitants of the Moon, having a diameter nearly four times as large as the Moon's, is more than twelve times as large as that which the Moon offers to the Earth. The Earth must, of course, rise and set to the Moon, and go through the various phases of light, just as we see is done by our celestial attendant, owing to the motion of the Moon round the earth; otherwise, the Earth will appear fixed in the heavens, relatively to the stars, because the earth is the centre of the Moon's motion. The Earth too would turn on its axis nearly thirty times, while the Moon is moving once round,—a rapidity which must seem astonishing to the Lunarians. The phases exhibited to the Moon by the Earth, must be always the reverse of those exhibited at the same time by the Moon to the Earth, as will be evident from inspecting the subsequent diagram. We may imagine what must be the feeling of intense curiosity with which those on the further side of the Moon seek for information concerning the splendid orb, visible to the other lunar hemisphere. Suppose now that we, in England, were to hear of a splendid moon, of vast dimensions, being visible to the



THE MOON.

inhabitants of the Sandwich Islands or New Zealand, and that we ourselves were without a moon, how eagerly would our navigators and travellers look out for the brilliant visiter, when they arrived at the line on the Earth's surface at which this spectacle became visible! At all seasons of the year, we see the Sun and also the Moon; this arises from the circumstance, that although the Earth revolves on her axis, yet the time which she takes in that rotation is neither that which she takes to revolve round the Sun, nor that which the Moon takes to revolve round the Earth. This is a striking instance of the great effects which often result from what we should, at first sight, deem slight causes. We know not whether any living beings inhabit the surface of the Moon; but if such be the case, they must be divided into two portions, very unequally favoured, as regards the view of the Earth, one portion having it always in sight, while to the other portion the Earth is altogether invisible.

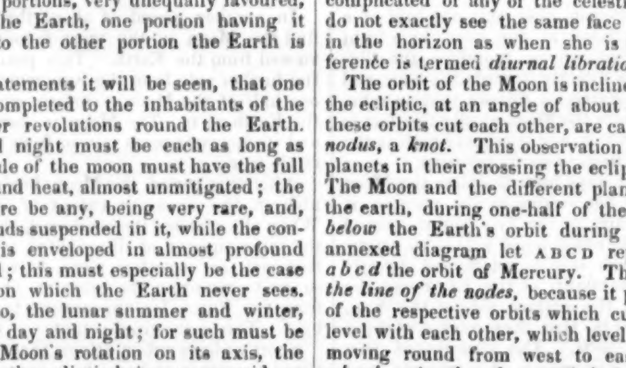
From the foregoing statements it will be seen, that one day and one night are completed to the inhabitants of the Moon during one of her revolutions round the Earth. Hence the lunar day and night must be each as long as 14¾ of our days. One side of the moon must have the full glare of the Sun's light and heat, almost unmitigated; the lunar atmosphere, if there be any, being very rare, and, therefore, not holding clouds suspended in it, while the contrary side of the Moon is enveloped in almost profound darkness and intense cold; this must especially be the case at that side of the Moon which the Earth never sees. From this will result, also, the lunar summer and winter, coincident with the lunar day and night; for such must be produced merely by the Moon's rotation on its axis, the inclination of this axis to the ecliptic being, as we said, so small as to produce no change of seasons.

Though, as was before said, we see only one side of the Moon, yet there is occasionally seen somewhat more than an exact hemisphere, which effect is termed *libration*, a word implying a *poising*, or *oscillation*, of the body of the Moon, owing to certain disturbing causes.

When a little of the further side of the Moon on either side is seen, owing to the irregularity of the Moon in her orbit, by reason of the attractions of the Sun and the Earth, this effect is termed the Moon's *libration in longitude:* and when, owing to the Moon's axis not being quite perpendicular to her orbit, a little of the further side of the Moon is seen at either of her poles, this effect is called the Moon's *libration in latitude.* Owing to the causes which produce these effects, the Moon's motion is the most irregular and complicated of any of the celestial bodies. Moreover, we do not exactly see the same face of the Moon when she is in the horizon as when she is in the zenith, which difference is termed *diurnal libration.*

The orbit of the Moon is inclined to that of the Earth, or the ecliptic, at an angle of about 5°; and the points, where these orbits cut each other, are called *nodes*, from the Latin *nodus*, a *knot*. This observation applies likewise to all the planets in their crossing the ecliptic, or orbit of the Earth. The Moon and the different planets are *above* the orbit of the earth, during one-half of their orbital revolutions, and *below* the Earth's orbit during the other half. In the annexed diagram let A B C D represent the ecliptic, and *a b c d* the orbit of Mercury. The dotted line *e f* is called *the line of the nodes*, because it passes through those parts of the respective orbits which cut each other, or are on a level with each other, which level is *e c a f*. The planet, in moving round from west to east, goes in the direction *a b c d; a* is, therefore, called the *ascending* node, *c* the *descending* node.

Fig. 16.



THE NODES OF A PLANET.

The word *disk*, so frequently used in reference to the Sun and Moon, implies a flat circular appearance, such as is presented by the Sun, Moon, and other heavenly bodies, when magnified; it is derived from the Greek word for *hurling*, the disk being a flat circular piece of metal, used in this exercise; we call it a *quoit.*

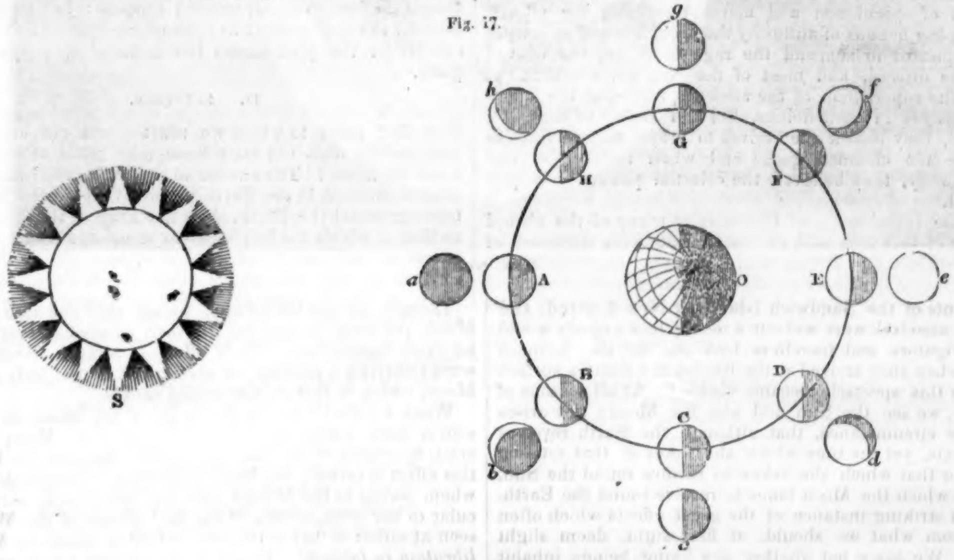
We shall now notice in order those phenomena presented by the Earth and Moon, which are dependant on their relative positions conjointly with the Sun: these may be considered as of three kinds; 1st, the Phases of the Moon; 2nd, Eclipses of the Sun and Moon; 3rd, Tides.

I. PHASES OF THE MOON.

WE have already stated, in general terms, the reason why an opaque body, such as a planet, must necessarily exhibit phases similar to those of the Moon. We may here add, that this observation applies especially to bodies whose orbit is within, or next to, that of the Earth. The planets Mercury, Venus, and Mars have been found to exhibit phases. The more distant planets present always a full face, owing to the great scope of their annual motions. The phases of the Moon, our nearest neighbour in the sky, are, however, so extremely interesting as a phenomenon, which bears reference to the Earth, that we deem it desirable to present in this place a figure illustrative of its causes and nature.

Let us imagine that S represents the Sun (supposed to be at a great distance off), that O represents the Earth, and A B C D, &c. the Moon at different parts of her orbit round the Earth. We will assume, in the first instance, that the moon is at A; in this position it will be perceived, that the enlightened half of the Moon is turned completely away from the Earth, while the dark half is presented towards the Earth.

Fig. 17.



PHASES OF THE MOON.

This results from the principle, that only one half of a globular body can be illuminated at one time, by a light proceeding from only one source; as, therefore, the illuminated half of the Moon is directly towards the Sun, and the dark half towards the Earth, it follows that an inhabitant of the Earth cannot see the Moon at all; this fact is represented by the black circle *a*, and whenever such is the case, the moon is said to be *new*, or in conjunction.

In about three and a half days from this time the Moon will have moved round in her course to the position B, which is called the first octant, or the first eighth part of her orbit. In this position the enlightened side is, as before, towards the Sun, but the dark side is not turned directly towards the earth; the inhabitants of the Earth see the Moon at some distance on the eastern side of the Sun, and the consequence of this is, that they catch a glimpse of the Moon's illuminated part. The illuminated part thus observed, presents the appearance of a crescent, and is represented by *b*. The points of this crescent are called the Moon's *horns*, or *cusps;* the latter word being derived from the Latin *cuspis*, a *point.* If we take note of the day on which a new moon occurs, as stated in an almanac, and watch for the actual appearance of the Moon about three days afterwards, we shall find that it presents the form of a luminous crescent, convex on one side and concave on the other, and, moreover, that the convex side is invariably turned towards the Sun.

After passing that position the Moon travels on to the position C, when she is said to be in quadrature,—that is, she has performed a quarter of her revolution round the Earth. In this position it will be found, that one half of her illuminated surface is visible to an inhabitant of the Earth, or that she appears as a semicircle as at *c*; this occurs in about a week after her conjunction.

Proceeding in her orbit she arrives at the position D, which is so far removed from the position A, that nearly the whole of the illuminated surface is visible to the Earth, at O. In this position the Moon is at her second octant, and presents an appearance such as *d*, in which about three-fourths of her illuminated surface is visible. This is the gibbous phase. The word *gibbous* is derived from a Hebrew word, implying *prominence* or *convexity.*

In another period of about three and a half days, we find the Moon in the most favourable position for being viewed from the Earth. This position is at E, which is on the further side from the Sun, which illuminates, as before, one half of the Moon's surface, and that half is visible to the Earth at O. The Moon is now *full*, or in opposition; and its appearance, as viewed from the Earth, is a luminous circle as *e*.

After this period the Moon begins to wane, or to diminish in the apparent extent of its illuminated surface. When she reaches the position F, she presents to the Earth the same amount of illuminated surface as at D; but the flattened, or imperfect edge, is turned somewhat round, so as to maintain its constant character of being away from the Sun. Its appearance to the eye is represented by *f*. This is the third octant.

Shortly afterwards it attains that position which is termed the last quarter, and which is represented at G. Here the general resemblance is to the position C, when the Moon was in the first quarter; and it is represented, as seen by the eye, at *g*. The last octant is at the point H, when the Moon has performed seven-eighths of her orbit round the Earth, and her appearance is that of a faint crescent of light as at *h*, which is equal in extent and brilliancy to the crescent *b*, which she presented about three weeks previously.

From this point she proceeds again to the point A, when she becomes again invisible to the Earth, on account of her illuminated surface being turned wholly away from the Earth: she may again be represented by the black circle *a*, and again obtains the name of New Moon, and is in conjunction.

Thus it appears that the different phases, or appearances of the Moon, admit of being satisfactorily explained on the two-fold principle, that she is an opaque body, reflecting the Sun's light, and that she revolves round the Earth from New Moon to New Moon. It is necessary here to observe, that although we are in the habit of considering the full Moon as a perfect circle, or disk of light, it is not so in reality. When we see the full Moon, she is either raised a little above, or depressed a little below, the straight line joining the Sun and Earth, and, therefore, there is a

small portion of her illuminated surface lost to, or turned away from, the Earth; this portion is at the upper part, when the Moon is above the line of which we have spoken, and at the lower part when she is below that line. When, however, the Moon is exactly in the direction of this line, or, in other words, when the Sun, the Moon, and the Earth are all in one straight line, some very remarkable effects are produced, which, under the name of *Eclipses*, have attracted a large share of attention in all ages. The principle is similar to that which we alluded to, in the case of the transits of the inferior planets; but when the Sun, Moon, and Earth are all concerned, the effects are more imposing upon the mass of mankind. In proportion to the ignorance of the cause of any operation of nature, is the amount of speculation and alarm respecting the effects. Among the nations of antiquity the occurrence of an eclipse was sufficient to suspend the rage of battle, the heat of intestine discord, and most of the common operations of life. The superstition of the ancients referring the apparent changes in their deities, Sol and Luna, to their own conduct, they betook themselves to prayer and sacrifice to appease the offended gods; and when the eclipse had passed away, they believed the celestial powers to be propitiated.

By the introduction of Christianity many of the absurd notions of this sort held by the ancients were dispelled, or greatly modified; but yet, until Astronomy was well understood, the fear of something supernatural constantly haunted the great bulk of mankind, believing, as the savage races of mankind do now, that when the motions of these three celestial bodies bring them into a line, the Sun

> . . . . . . From behind the moon
> In dim eclipse disastrous twilight sheds
> On half the nations, and with fear of change
> Perplexes monarchs.—MILTON'S *Par. Lost*, b. i.

The phenomena of the heavens have often been resorted to by designing men, to impose upon the credulity or fears of the unintellectual part of mankind. We read that Columbus, when in the island of Jamaica, in the year 1503, was reduced by dread of famine to resort to an imposition of this sort to procure provisions. Columbus and his crew, having been wrecked, had consumed their small stock of provisions, and having to depend upon the natives, with whom many untoward circumstances had prevented them from being upon good terms, it struck Columbus, who had a great knowledge of Astronomy, that an approaching eclipse of the Moon might serve his purpose of awing the natives. He accordingly summoned their chiefs to a council on the evening of the eclipse, and told them that the deity of the skies, whom they served, was angry with the Indians for withholding provisions from the Spaniards; that the Indians would be punished in a signal manner; in token whereof the full Moon, then riding in majesty across the celestial dome, would be deprived of her light, and held in black durance. Some treated this announcement with contempt, while others were alarmed, but all were naturally anxious. When they at length saw the black shadow of the Earth seizing the Moon within itself they were all horror-struck, and, hastening to the crew with provisions of all sorts, they begged the intercession of Columbus with the celestial deity that the Moon might be restored, promising to serve Columbus faithfully ever after. Columbus, after retiring for some time to consult the deity, as he said, promised them that the curse would be taken off from them; and that, as a sign, the Moon would emerge from her confinement; which, when the Indians saw again traversing the heavens, they adored the astronomer, believing him to have supernatural gifts, and to hold an intercourse with heaven, whereby he was informed of what would take place in the skies. The Spaniards suffered no more upon this occasion through famine.

It appears that some of the earliest efforts of astronomers were directed to the prediction of eclipses: how far the power of predicting the occurrence of an eclipse was really possessed by the early Chinese, Hindoos, and Chaldæans, seems to be a matter of much dispute among the learned; sufficient evidence remains, however, to show that extraordinary attention was bestowed upon these phenomena. To attempt to explain the manner in which the astronomer is enabled to predict the return of an eclipse, would be altogether foreign to our present purpose; but we shall endeavour to show in what way the obscuration of light, which obtains for the phenomena the name of an *eclipse*, takes place.

II. ECLIPSES.

THE first point to which we must direct our attention is this:—Why does not an eclipse take place at *every* New and Full Moon? The answer to this is, because the Moon's orbit is inclined to the Earth's orbit; that is, the Moon, in moving round the Earth, does not keep in the same plane as that in which the Earth moves round the Sun. The two planes are inclined to each other at an angle of about 5¼°, so that in one part of her orbit, the Moon is above the place of the Earth's orbit, and in another part she is below that plane. Now, it is obvious, that only at the times she is in either of her nodes is she in the plane of the Earth's orbit.

Hence it is only when the Moon is *at* or *near* one of her nodes, at the time of New or Full Moon, that an eclipse can happen; so that, if she be far removed from her nodes at New or Full Moon, she is altogether above or below the line which joins the Earth and the Sun; but if she be exactly at the node, there will be a *central* eclipse, and if she be within certain limits on either side of one of her nodes, there will be a *partial* eclipse.

SOLAR ECLIPSES.

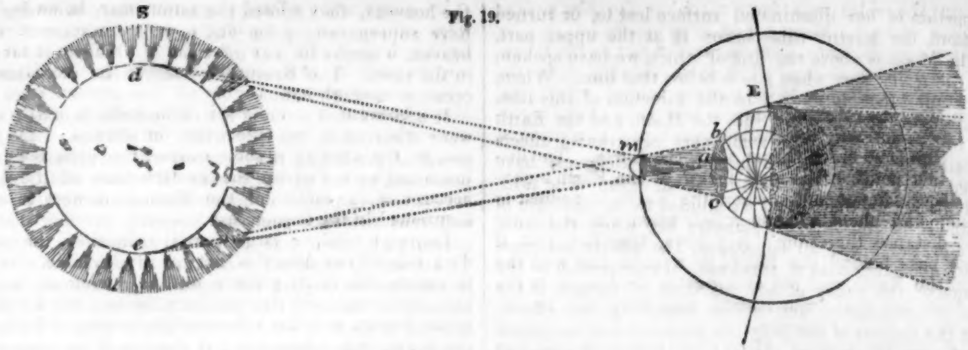
THIS being premised, we are in a condition to understand the phenomenon of an eclipse of the Sun, to which we shall now more particularly give our attention. Let S (figs. 18 and 19), represent the Sun, E the Earth in its orbit, and *m* the Moon in conjunction. A circle surrounds the Earth, which may be considered to represent the Moon's orbit. If the Moon were not present, exactly one-half of the Earth's surface would be illuminated by the Sun; but an obstruction to the Sun's light is offered by the Moon interposing. We have, therefore, the Moon *m* between the Earth and the Sun, and at or near one of her nodes; so that she is not only in the same vertical plane as the Earth and the Sun, but in the same right line with them. If they be not precisely in the same right line, as shown in our figures, there may, at any rate, be a *partial* eclipse of the Sun, if the Moon be within 17° 21′ of her node at the time of conjunction, or new moon.

Now, when we hold a ball before a candle, not only is there one half of the surface of the ball in darkness, but there is a long shadow behind the ball, occasioned by the interruption which the ball presents to the free progress of the light in that direction. If we hold a second object in this shadow, we cannot see it by the direct light of the candle; the view which we may obtain of it being by light reflected from other parts of the room; and if we were in a

Fig. 18.

TOTAL ECLIPSE.

Fig. 19.



ANNULAR ECLIPSE.

large open space where no objects were present to afford this secondary reflection, we should find the object immersed in the shadow to be almost entirely invisible. Reasoning thus in the case of the Moon and the Earth, we find a strict analogy: a flood of light is shed by the Sun on the Moon at *m*, by which its front surface is wholly illuminated, and its hinder surface kept in the shade: there is also a shadow cast behind the opaque body of the Moon, the extent of which shadow depends conjointly on the sizes of the Sun and Moon and the distance between them. This shadow is of two kinds, the *umbra** and the *penumbra;* the former being the darker of the two: the reason of this difference is, that the umbra covers a portion of space wholly deprived of the Sun's light, while the penumbra covers that portion of the Earth's surface which has a view of *part* of the Sun's disk. Were the Sun but a luminous point, this distinction would not occur; but, as he has a very considerable diameter, and the Moon is very small compared even with the Earth, it follows that there will be no eclipse to places out of the penumbra; that places in the penumbra will have the Sun partially eclipsed; and that places in the umbra will see a total, or an annular, eclipse of the Sun; the latter depending upon the distance of the Moon from the Earth. The first of the two foregoing figures represents a *total*, the second an *annular* eclipse.

The Moon *m* being exactly between the Earth and the Sun, throws her dark conical shadow *m a* towards the Earth, which shadow, in the first case, reaches the Earth, and in the second falls short of it.

If now we suppose an inhabitant of the Earth to be situated at the point *a*, (fig. 18,) he would witness a total eclipse of the Sun: he will be situated in the shadow of the Moon, and the body of the Moon will completely hide the Sun from his sight; this will be evident, when it is seen that he will be in the shadow, between the lines *d a*, *e a*. If another inhabitant of the Earth were situated at any point between *b* and *a*, or *a* and *c*, he would see a partial solar eclipse, that is, the black disk of the Moon would appear to cut off a portion of the luminous surface of the Sun. The parts of the Earth beyond *b* and *c*, on either side, are out of the effects of the eclipse: the people beyond *b* and *c* see the whole disk of the Sun, as is plain by observing the direction of the lines *b e* and *c d*.

If the Moon were at a constant distance from the Earth, and the Earth at a constant distance from the Sun, a central eclipse of the Sun would always present the same features to an inhabitant of the Earth; but such is not the case: the Earth is about three millions of miles nearer to the Sun in December than in June, on account of her being at that end of her elliptical orbit which is nearest to the Sun; consequently the Sun appears larger, or subtends a larger angle, at the former period than at the latter. Again, the Moon's orbit round the Earth is likewise elliptical; and although we are accustomed to say that the Moon is about 240,000 miles distant from the Earth, yet, when we wish to determine the distance in different times, it is found that the Moon's greatest distance from the Earth is about 251,000 miles, and her least about 227,000. Now, if the Moon were in *perigee* (that part of her orbit nearest to the Earth), and the Earth were in *aphelion* (that part of her orbit farthest from the Sun), at the time of a central solar eclipse, the eclipse would be total, because the apparent diameter of the Moon, as seen from the Earth, would be greater than that of the Sun. But if the reverse were the case; if the Moon were at her greatest, and the Sun at his least, distance from the Earth, at the time of a central eclipse, then the eclipse would be annular†; that is, a ring of the Sun's light would seem to surround the dark body of the Moon, in consequence of the Sun having at that time a larger apparent diameter than the Moon. These differences would not occur, were it not that the apparent dimensions of the Sun and Moon, as seen from the Earth, are so nearly equal.

Hence it will be seen, by inspecting the second figure, that, in an annular eclipse, no part of the Earth can be enveloped in the Moon's umbra, owing to its not reaching the Earth; and the solar ring can be seen only by that part of the Earth where the umbra would have fallen, if the Moon had been nearer the Earth; that is, under the point *a*, where a straight line would reach which had passed through the centres of the Sun and Moon. The part of the Earth out of this spot, but between *b* and *c*, sees only a partial eclipse, and those beyond *b* and *c* none at all.

In order to obtain some means for estimating the magnitude of an eclipse, the diameter of the Sun or Moon is supposed to be divided into twelve equal parts, called *digits;* so that when it is said that such a number of digits was eclipsed, the meaning is at once known: the Moon was not in a node at the time of the eclipse, the eclipse was therefore partial, not central, and the number of digits indicates to what extent of surface the eclipse advanced.

Calculations have been made as to the longest time that a solar eclipse can be either central, or annular, under the most favourable circumstances; and it has been found that 12 minutes 24 seconds is the longest time of an annular eclipse, and 7 minutes 58 seconds the longest time of a total eclipse.

The periods which the Earth and Moon take to perform their respective revolutions, and the degree of obliquity between their orbits, have enabled astronomers to calculate how many eclipses may occur in a year. There must be two eclipses of the Sun in every year, and the number may be as high as five, but it cannot be greater. No solar eclipse is visible in every part of the portion of the Earth which is turned towards the Sun, because the shadow of the Moon is too narrow to take in the whole diameter of the Earth at once, as may be seen in the preceding figures. A solar eclipse cannot be total at the same moment to a portion of the Earth more than 180 miles in diameter; but it may be partial at the same moment to a portion of the Earth 4900 miles in diameter. We may further observe that a solar eclipse does not happen at the same point of time at all places where it is perceived: it appears earlier to those persons situated towards the west, than to those situated towards the east, because the motion of the Moon and of her shadow is from west to east. Moreover, the extent of solar obscuration is different at different latitudes on the Earth's surface; according as we may suppose a spectator to be more or less distant from the line which connects the three bodies in question.

LUNAR ECLIPSES.

As the solar eclipse was owing to the opaque body of the Moon hiding the light of the Sun from the Earth, and took place when the Moon was new, or in conjunction; so the lunar eclipse is due to the opaque body of the Earth

* *Umbra* is the Latin for *a shadow; penumbra* implies *a partial shadow.*

† So termed from *annulus*, the Latin for *a ring*.

hindering the solar rays from reaching the Moon, and takes place when the Moon is full, or in opposition.

In the subjoined figure, S represents the Sun, E the Earth, *m* the Moon in opposition. The Sun, shining upon the Earth, causes a shadow to be thrown behind, which has the form of a cone; that is, it tapers to a point like a sugar-loaf. The reason why the shadow thus tapers to a point is, that the Sun is so much larger than the Earth. The distance of this point, or the total length of the Earth's shadow, is about 840,000 miles, when the Earth is nearest to the Sun; and about 870,000 miles, when she is at her farthest distance therefrom: it follows, therefore, that if any body pass behind the Earth, in a right line with the Sun and the Earth, and not at a greater distance from the Earth than has just been named, that body will be immersed in the Earth's shadow.

This is the case with the Moon: we have seen that she is, on an average, about 240,000 miles distant from the Earth; and that she revolves round the Earth in a plane nearly coincident with the plane of the Earth's orbit. In our figure the shadow of the Earth is represented as having a conical tendency; if now the Moon *m* were beyond the apex of this cone, she would altogether escape from the Earth's shadow, but, as part of her orbit (which is represented by the circle,) is between the base and the apex of the shadow, the Moon is necessarily immersed in the shadow, and we thus have the phenomenon known as an eclipse of the Moon. If the Moon happen to be at one of her nodes at the time of full Moon, then we have a central and total eclipse; but if she be at any part of her orbit not exceeding $11^\circ 21'$ from the node, the eclipse will be partial. In this case, the three bodies cannot be in a perfectly straight line; so that the Moon dips more or less of its body into the shadow of the Earth, but not the whole of its body.

Some time before the commencement of an eclipse of the Moon, she is seen to be partially obscured, as if a mist covered the illuminated surface: this arises from the circumstance that she has to go through the Earth's penumbra, or partial shadow, before her immersion in the umbra, or real shadow. In our figure, rays of light from the two extreme edges of the Sun $a\,a'$, pass by the edges of the Earth $b\,b'$, (having previously crossed at c,) and go on in the direction $b\,d$ and $b'\,e$: but still the upper part of the penumbra $d\,b\,f$, receives light from the upper part of the Sun, although the Earth prevents it from receiving light from the lower part; and, again, the lower part $g\,b'\,e$ of the penumbra receives light from the lower part of the Sun, although the upper rays are also excluded by the Earth. From this circumstance, therefore, the real shadow is surrounded by a partial shadow, which imparts to the Moon the dusky appearance just mentioned, which duskiness becomes more decided as the Moon approaches the real shadow, and so receives fewer rays from the Sun. If there be inhabitants in the Moon, they, of course, see a solar eclipse; and, while they are in the Earth's penumbra, the Sun appears to them partially eclipsed, which solar eclipse increases until the Moon enters into the Earth's umbra; when the Sun appears to the Moon, and the Moon appears to the Earth, totally eclipsed.

By comparing the foregoing circumstances, we find that a solar eclipse can be visible to only a portion of the enlightened hemisphere of the Earth: while a lunar eclipse may be seen by half the globe of the Earth. Moreover, a lunar eclipse always begins on the eastern edge of the Moon, because her motion is from west to east; so that her eastern edge first enters into the shadow of the Earth: but, in the case of a solar eclipse, the dark body of the moon appears first on the western limb of the Sun, on account of the motion of the Moon from west to east, as mentioned in the former case.

During a total, or large partial eclipse of the Sun, the dark side of the Moon is not wholly invisible. We can, therefore, descry its general outline, owing to the Sun's light being reflected strongly from the surface of the Earth to the Moon; and this reflected light is again reflected from the Moon, and constitutes the faint light on her surface seen during a solar eclipse, and also in a very interesting manner, when the Moon is only two or three days old. The disk of the Earth appearing to the Moon nearly thirteen times as large as the Moon appears to us, the light which the Earth gives the Moon must be very great. Now, when the Moon is two or three days old, the Earth appears as a large gibbous figure of light to the Moon; and so we see not only the sun-lit part of the moon, but also the rest of its disk, seeming of a dirty white plaister colour. As the light of the Sun increases upon the disk of the moon, the Earth's light to the Moon wanes, and we no longer notice this appearance.

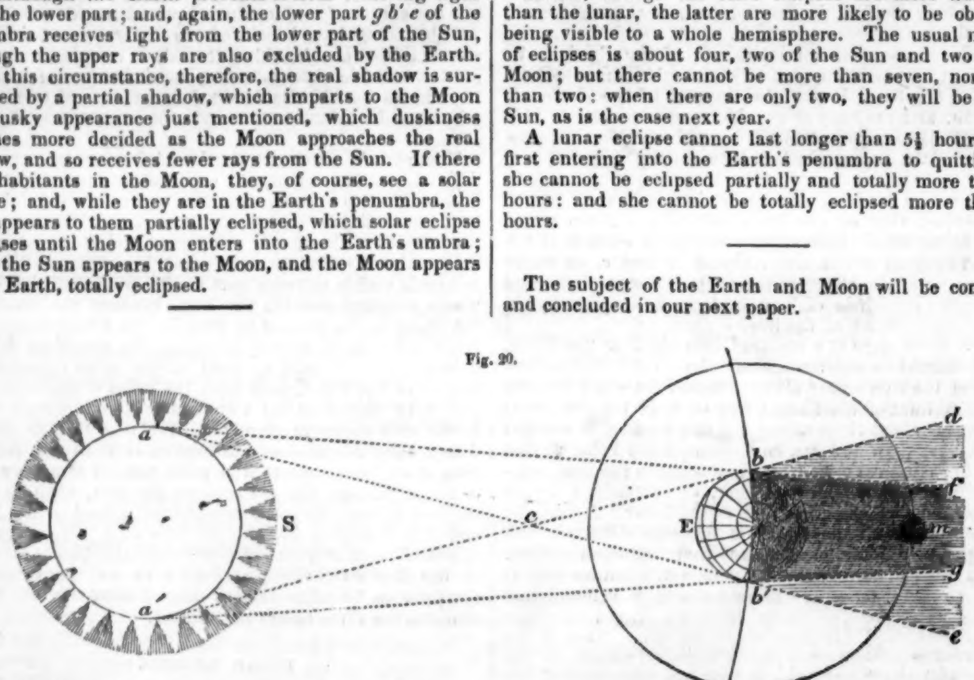
In a total eclipse of the Moon this body is still seen, even when enveloped in the shadow of the Earth, by reason that the rays of light from the Sun are bent round the margin of the Earth by the refracting power of its atmosphere, and are thus carried on through space till they arrive at the Moon; from the surface of which they are again reflected. It is further evident that an eclipse of the Sun cannot be identical as to time and appearance, to any two spectators situated at different points on the Earth's surface; because the sun loses no light, but is only hidden, as it were, by a screen, scarcely, or just big enough to hide it: but an eclipse of the Moon is identical as to time and appearance, because it loses its light, and that too, at a certain precise point of time:—that is to say, we may see the Sun at the time of a solar eclipse, and be ignorant that he is eclipsed; but a lunar eclipse is seen by all, who see the moon.

Hence, though the solar eclipses are more numerous than the lunar, the latter are more likely to be observed, being visible to a whole hemisphere. The usual number of eclipses is about four, two of the Sun and two of the Moon; but there cannot be more than seven, nor fewer than two: when there are only two, they will be of the Sun, as is the case next year.

A lunar eclipse cannot last longer than 5½ hours, from first entering into the Earth's penumbra to quitting it: she cannot be eclipsed partially and totally more than 3¾ hours: and she cannot be totally eclipsed more than 1¾ hours.

The subject of the Earth and Moon will be continued and concluded in our next paper.

Fig. 20.



A LUNAR ECLIPSE.

LONDON: Published by JOHN WILLIAM PARKER, West Strand; and sold by all Booksellers.